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Enhancing Urban Trails Design Quality by Using Electroencephalography Device

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Abstract

Enhancing urban trails design quality can encourage people to use them. This study compared two urban trails with different functions in Tehran. Trying to discover that while walking on the urban trails which parts of the path has the most effects on the cognitive functions of users. The aim is to enhance the urban trails quality by understanding human's reaction. We use electroencephalography device as a cognitive science tool. Results illustrate that first three minutes of strolling has the most cognitive effects on users. We suggest improving the space quality of urban trails after the first minutes of entrancing.

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Keywords: Urban trails; EEG; park; commercial walkway

1. Introduction

Today cities are developed to have more walkways and walking strategies (Azmi & Karim, 2012). Urban trails are the walkways in the cities that build for encouraging people to stroll in them. Urban trails have a direct relation to users. Researchers show that walking and cycling in urban trails can have positive effects on user's mental and physical well-being (Shamsuddin, Hassan, & Bilyamin, 2012). Other studies show that having urban trails near residential neighbourhoods can encourage children to play in them (Aziz & Said, 2012).

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Studies proved that design quality have some influences on people’s desire to use the place (Mansor, Said, & Mohamad, 2010; Mohamed & Othman, 2012). Architects and urban designers try to design in a way that encourage people to be in a place and enjoy the ambience (Shirotsuki, Otsuki, & Sonoda, 2010). Urban trails are necessary for citizen’s health and activity, and they should have a human oriented design (Shamsuddin et al., 2012). As urban trails have a direct relation to users and influence their health, enhancing their design quality can encourage people to use them more and be healthy (Hashim, Isnin, Ismail, Norrihan, & Razali, 2012; Marans, 2012).

Architects design urban walkways in the way that people can stroll in them for a while, and most of them have some starting and ending points. Walking ways usually have long distance and because of that people would get bored while strolling. Hence, their design should be in an exciting and motivating way(Ujang, 2010). Usually for creating long walkways designers try to create noticeable signs in different places to catch the attention of people. This study attempts to find out the changes of people’s emotions and cognitive functions toward urban spaces by focusing on the time of strolling in urban trails.

Neuroscience and cognitive science are new ways to study people’s reaction toward the environment(Vartanian et al., 2013). Using these new technologies can improve architectural researches. The aim of this research is to enhance the urban trails quality by using cognitive tools and understanding human’s reaction. This research tries to find out that while walking on the urban trails which part of the path has the most effects on the cognitive functions of users. This study seeks to improve the design, according to user’s needs. As a result, we use neuroscience tools to recognize people’s reaction to the space. Therefore, we design a study to compare two different urban trails such as; recreational (park) and commercial (bazaar) walkways, according to calmness and excitement feelings. We test the feeling by using neuroscience research tools.

1.1. Cognitive science and design

Developments and improvements in cognitive science tools lead architects and urban designers to use these new technologies in their researches. Cognitive science research tools can help designers to recognize people reactions toward environment better and to do human-oriented design. Historically, architectural research relied on philosophical constructs or analysis of behaviour patterns in order to relate human responses to design (Pardalos, 2012, p. 28). Two major research methodologies and one design process have been developed for environmental behaviour studies mainly to relate to architecture and other design professions and processes. Those are user needs programming studies, post-occupancy evaluation (POE) studies, and evidence-based design(Eberhard, 2009, p. 171). The knowledge that is developed in this field enriched architectural studies.

Environment-Behaviour studies—user needs studies and POEs—can help us understand what kind of the relationship might be between designed environments and behavioral outcomes. They will never be able to tell us, from a physiological and neuroscience point of view, “why” these relationships occur. It requires that neuroscience knowledge to be applied (Eberhard, 2009, p. 177). There is a gap between architecture and psychology in phenomena understanding between. While, neuroscientific data have an important role to play in bridging the conceptual gap between architecture and psychology by explaining some of the underlying mechanisms. The mechanisms that explain how systematic variations in architectural features lead to behavioral outcomes (Vartanian et al., 2013). In this paper, we try to answer one of these “why” questions. Why after strolling for few minutes we lose the ambience of the environment?

Research devices in neuroscience such as; Electroencephalography (EEG), Functional magnetic resonance imaging (fMRI), Eye tracking, etc. can be used in architecture and environmental researches. Many studies were performed by these devices. For example, studying systematic variation in contour impacts aesthetic judgments and approach-avoidance decisions by using a functional magnetic resonance imaging (fMRI) (Vartanian et al., 2013). Their results show that participants were more likely to judge spaces as beautiful if they were curvilinear than rectilinear. Also, there are lots of works in colors according to neuroscience and physiological data (Jalil, Yunus, & Said, 2012).

1.2. Electroencephalography (EEG)

EEG is a device in the neuroscience field that has usage in both clinical and research areas (Buzsaki, 2009). EEG device records the electrical activity along the scalp. EEG possesses many advantages over other brain monitoring tools, like its lower costs and few side effects for patient (Niedermeyer & da Silva, 2005, p. 17). EEG signals divided into bands by frequencies. Four basebands are Alpha, Beta, Delta and Theta.

Alpha is the frequency range from 7 to 13 Hz it is usually seen in the posterior regions of the head on both sides (Sadock, 2000, p. 159). Alpha is most often associated with quiet, passive, resting, but wakeful states (Zillmer, Spiers, & Culbertson, 2008, p. 41).

Beta is a low-amplitude, fast-activity wave with a frequency of more than 13Hz. Beta is usually seen in frontal lobe and is often divided into high beta (24–30 Hz), typically related to a narrow focus, over-arousal, and anxiety; mid-beta (18–24 Hz), often linked to being active, alert, excited, or focused; and low beta (13–18 Hz), which has been connected with relaxed, external attention (Zillmer et al., 2008, p. 41).

Delta is the frequency range up to 3.5 Hz. It is normally considered in adults in deep sleep. Also, Theta is the frequency between 4 Hz to 7 Hz; sometimes Theta can be seen in the frontal lobe in healthy adults (Sadock, 2000, p. 159). In this study, we focused on Alpha and Mid-Beta bands because these two shows the calmness and excitement level, which we want to work on them in park and bazaar.

Many studies worked on EEG in relation to the environment. One study focused on the impact of fluorescent light on neurophysiological, and subjective indices of wellbeing and stress(R Küller & Wetterberg, 1993). Other studies show that we can use mobile EEG such as; Emotiv device in architecture and urban design for studying real environment, also this study shows some evidence to use EEG in acoustic researches(Roe, Aspinall, Mavros, & Coyne, 2013). Furthermore, another study worked on EEG signals for evaluating the arousal and performance toward the interior color (Rikard Küller, Mikellides, & Janssens, 2009). These references show the usage of EEG in environmental studies.

2. Materials and methods

2.1. Study design

This study was intended to clarify the effects of urban trails on cognitive functions of users while strolling. We compared two different urban trails with recreational (Park-e-Shahr) and commercial function (Sepah-Salar) in Tehran (Fig.1).

Fig. 1. Locations of two urban trails in Tehran, Iran (Park-E-Shahr and Sepah-Salar).
(Sources: Google Maps, 2015)

First we analysed these two walkways based on the SWOT chart. SWOT (strength, weakness, opportunity, threat) analyses involve brainstorming and recording a place’s strengths and weaknesses, the opportunities that could be exploited and the likely threats(Carmona, 2010, p. 304).

We chose two walkways that had the same design quality. Both of them had North-South orientation with 10 m width and 250-300 m length. 20 healthy subjects (9 men and 11 women) participated in this study and their average

age was29 years old (20 to 35). It was a convenience sampling, and they were volunteers from university students with different academic majors. Participants shouldn't be addicted to a cigarette, alcohol and, etc. Also, they shouldn't have any mental disease like; depression, stress and, etc. Moreover, they shouldn't use any kind of drugs related to mental health. We asked participants about their level of health for choosing them for the test. Furthermore, we had a 1 minute EEG test with an open eye before the experiment from all of the participants to check any specific mental problem.

Participants were strolling the ways for about 10 minutes while the EEG EMOTIV device was recording their brain functions. EEG signals were recorded by the Emotiv EPOC device with 14 channels. All the recording was done between 11 a.m to 13 p.m working days.

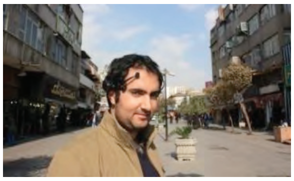

Fig. 2. (a) Participant with Emotiv device on his head in Commercial trail (Bazaar); (b) Participant with Emotiv device on his head in Park; (c) Emotiv device.

(Sources: (a&b) Authors,2014; (c) Emotiv Epoc, 2014)

Emotiv is a mobile EEG device. In this study, EEG signals were recorded by a laptop that the researcher was carrying and following the participants carefully from 2-3 meters distance. It helps the researcher to check the signals while recording and notice any problem during the examination. After the experiment participants answered to some questions such as; how many times, they have visited these walkways.

We can deduce that the park is the place for being relaxed and commercial is for being excited. Therefore, designers try to improve these feelings by design. Hence, in this study we examined calmness and excitement level in a park and commercial trails to understand their changes, according to urban trails. This was a pilot study in neuroscience and architecture that had limitations such as; participant's number, age, gender and data sampling that perform in a specific time in Tehran.

2.2. Data processing and statistical analysis

EEG studies show that frequency changes of each part of the brain has different meaning (Zillmer et al., 2008, p. 40). Researches in neuroscience field show that relaxing is related to 7-13Hz (Alpha) changes of occipital part of the head and excitement is related to 18-24 Hz (Mid-Beta) changes of frontal part of the head (Zillmer et al., 2008, p. 41). Therefore, in this study we calculated frequency changes for relaxing and exciting in those two parts of the head.

There is a standard way for analyzing EEG signals(Zillmer et al., 2008, p. 44) that we worked on them. EEG signals were recorded by Emotiv EPOC device according to 10-20 standards with 14 channels with references to both mastoids. Its channels include AF3, AF4, F3, F4, F7, F8, FC5, FC6, T7, T8, P7, P8, O1 and O2. In this paper, we analyzed AF3, AF4, O1 and O2 channels. Also, Frequency sampling was 128 Hz. Fig. 3 shows the channel locations of electrodes for occipital and frontal lobe.

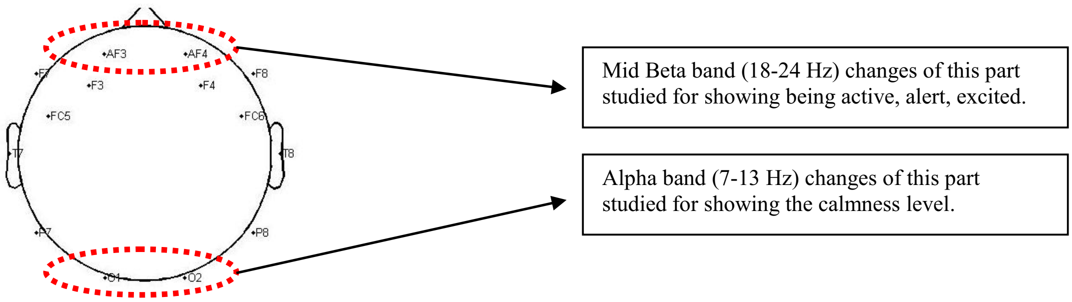

Fig. 3. Channel locations of EEG, we worked on AF3,AF4, O1 and O2.
(Sources: Authors, 2015)

We analysed EEG results with EEGLAB and MATLAB software. Paired samples t-test was done for signifying the data ($p<0.05$). EEG frequency bands were Extracted, and High-pass filtering EEG at 0.1 Hz was done. Also, Direct Current (DC offset) was removed from the EEG signals. We need to filter EEG signals. EEG records electrical signals and can record all the external and internal unwanted signals that exist around us. FFT extracted sub frequencies signals, such as; Alpha and Beta (FFT is the standard code in MATLAB that extract waves into sub frequencies). We divided time into three equal parts and examined each period according to calmness and excitement (active thinking) changes and drew the charts for each part.

3. Results

Carmona defined six different dimensions for urban design, such as; morphological, perceptual, social, visual, functional and temporal dimensions(Carmona, 2010). In this study, we focus on the visual dimension and compare these two urban trails in this field with SWOT chart. Buildings, streets and spaces, hard and soft landscaping and street furniture should be considered together, to create visual interest and to enhance the sense of place (Carmona, 2010, p. 164). In visual dimension, we worked on townscape aesthetic, serial visions, height-to-width ratio, rhythm and harmony. We try to describe commercial and park walkways in the plan, section and photos in Fig 4&5.

Fig. 4. (a) Section-Commercial trail (Sepah Salar, Tehran, Iran); (b) Site plan-Commercial trail; (c) different views of the commercial trail. (Sources: Authors, 2014)

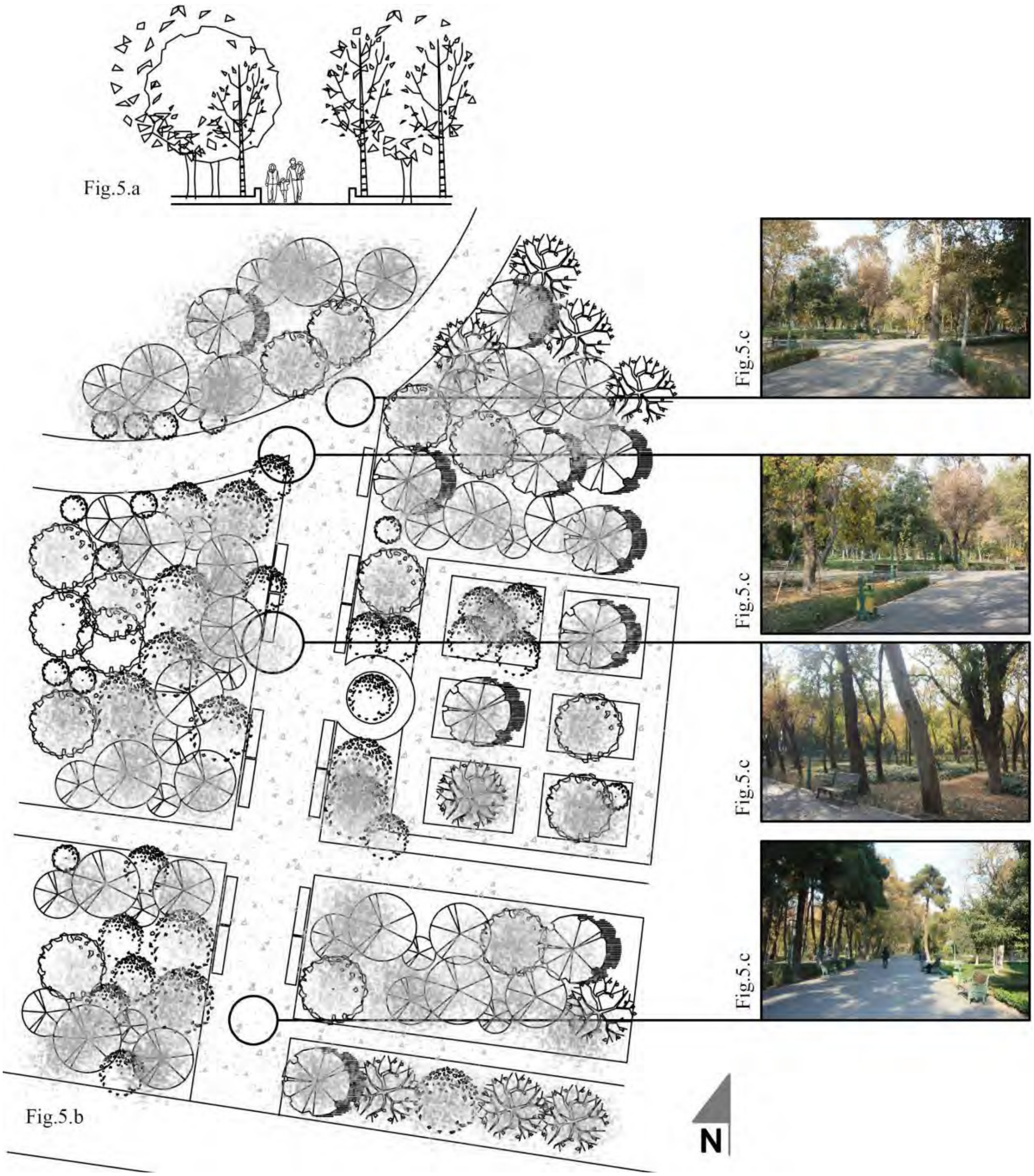

Fig. 5. (a) Section-Recreational trail (Park-E- Shahr, Tehran,Iran); (b) Site plan- Park; (c) Different views from the park.

(Sources: Authors, 2014)

We compared two walkways with SWOT analyses. Table 1 shows the SWOT analyses result according to the visual dimension. It shows that both walkways have the same level of strengths and weaknesses in the visual dimension. It illustrates that the design quality of both of them are the same.

Table 1. SWOT analysis according to visual dimensions for park and commercial trails.

	Urban Design Dimensions (Visual Dimension)	
	Park	**Commercial**
Strength	Trees make soft landscape	Shop's facade make the townscape active
	Having statue and landscape facilities	Having statue and landscape facilities
	Trees have fabulous harmony	
Weakness	Monotone serial visions	Monotone serial visions
	Monotone Height-to-width ratio	Monotone Height-to-width ratio
	Not suitable pedestrian materials	Weaknesses in townscape aesthetics by paying no attention to rhythm, color, harmony, etc.
		Façade's old materials
Opportunity	Natural aesthetic potential of old trees	Shops have high potential to rebuild the townscape
Threat	Few number of visitors	Lack of harmony in building new shops

(Sources: Authors, 2015)

Furthermore, Interviews after the test showed that the average of the subjects has seen a park and commercial pedestrian once before or once a year. It shows that the experiment locations were not regular and usual places for the subjects. Therefore, it can cause the participants to pay more attention to the environment.

Table 2. shows Alpha changes in park and bazaar (commercial trail) for each period. The Paired samples t-test has significant meaning in the first period (p=0.04). Also, Fig. 6(a). shows that the level of Alpha in the park for the first period is higher than Beta.

Table 2. Paired Sample T-Test for Alpha band (7-13 Hz) in each period for the park and Bazaar- (*P<0.05).

		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	*Sig. (2-tailed)
					Lower	Upper			
Pair (1st period)	Alpha park1 – Alpha bazaar1	.002054368	.003209006	.000890018	.000115185	.003993551	2.308	12	.040
Pair (2nd period)	Alpha park2 – Alpha bazaar2	-.001172974	.003688016	.000824665	-.002899019	.000553071	-1.422	19	.171
Pair (3rd period)	Alpha park3 – Alpha bazaar3	-.001383742	.004344843	.000971536	-.003417191	.000649707	-1.424	19	.171

(Sources: Authors, 2015)

Table 3. shows the Mid-Beta changes in the park and commercial trial for each period. It illustrates that the first period has significant meaning (p=0.033). Also, Fig. 6(b). shows that the level of Mid-Beta in the bazaar is higher than the park.

Table 3. Paired Sample T-Test for Mid-Beta band (18-24 Hz) in each period for the park and Bazaar- (*P<0.05).

	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	*Sig. (2-
				Lower	Upper			

									tailed)
Pair (1st period)	Beta park1 – Beta bazaar1	-.000053492	.000083895	.000022422	-.000101932	-.000005052	-2.386	13	.033
Pair (2nd period)	Beta park2 – Beta bazaar2	.000024043	.000084873	.000018978	-.000015679	.000063765	1.267	19	.221
Pair (3rd period)	Beta park3 – Beta bazaar3	-.000023598	.000099364	.000022218	-.000070102	.000022906	-1.062	19	.302

(Sources: Authors, 2015)

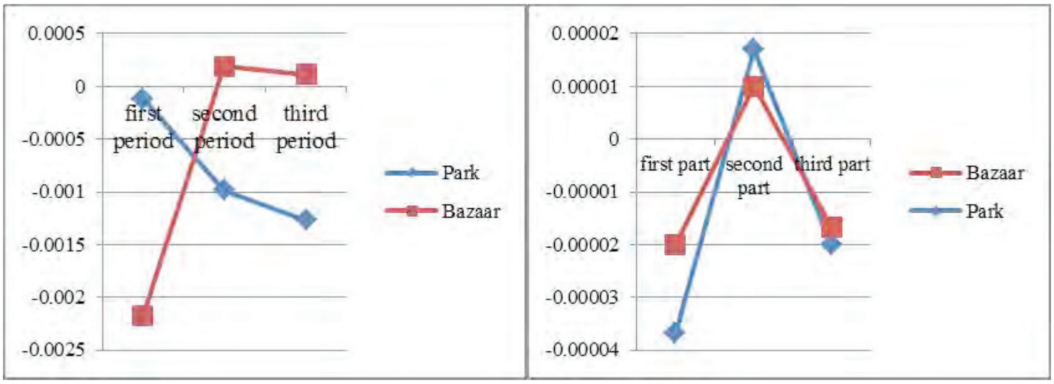

Fig.6. (a) Comparing Alpha changes (relaxing) in each period for park and bazaar,(b) Comparing Mid-Beta changes (excitement) in each period for park and bazaar.
(Sources: Authors, 2015)

Moreover, Fig.7. Shows the average of the brain maps in each band (Alpha and Mid-Beta) in a park and commercial trail. Warm colors show the more activity of each part of the brain. Hence, comparing the brain maps shows that the Alpha activity of the occipital part in the park is higher than the bazaar that illustrates relaxing feeling in the park. Also, Mid-Beta activity in the bazaar of the frontal lobe is greater than the park that shows more excitement.

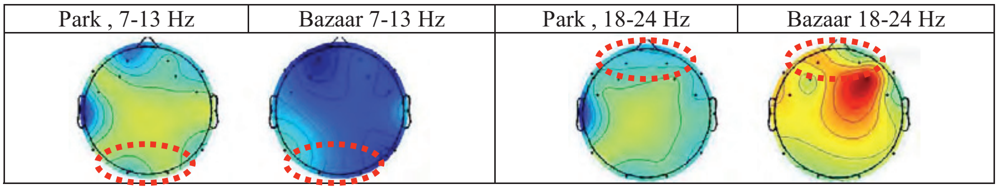

Fig.7. Average of Brain maps for Alpha (7-13 Hz) and Mid-beta (18-24 Hz) in park and bazaar.
(Sources: Authors, 2015)

4. Discussion

For studying design's effects on people, we chose two walkways with the equal design quality. The SWOT analysis showed that they had similar strength and weaknesses. It is deducible that the park makes us feel calm, and bazaar makes us feel the excitement (Saffuan, Ariffin, & Amin, 2013). This study showed that these ambiences fade after some minutes. Results illustrated that first period (0-3 minutes) had the most cognitive and emotional effects on users in relation to space function. In addition, EEG results showed that the relaxing level was significantly higher in the first period in the park and decreased during the time. Also, EEG findings in the commercial walkway demonstrated that the excitement level was significantly greater in the first period and reduced by the time passing.

SWOT analysis showed that these two urban trails did not have any attractive points and had a monotone design. EEG results showed that after a few minutes people lost their ambience of the space. Therefore, it showed that monotone design was not suitable for walkways, and there should be some eye-catching points in the design.

5. Conclusion

As a conclusion, we suggest designers to improve the space quality of urban trails after the first 3 minutes of entrancing for attracting users. This study showed that the primary moments of strolling in the area had the most effects on people, and they felt the environment ambience. After walking for some minutes, the effects of the space faded. Hence, for catching the attention of people, we suggest putting some noticeable elements in this part of the way and improve the design.

Previous researches in the environmental psychology field do not answer that *why* participants show specific reaction towards the environment. Hence, neuro-architectural studies aim to answer these kinds of questions. We performed this study in the real world and tried to have the same conditions for each participant. According to its limitations such as; ages, gender, location and time we suggest researchers to perform more studies in this field in different urban places and work on age and gender. This area is the new generation of studies in architecture and urban design related to neuroscience that has its limitation and difficulties. In this paper, we tried to simplify the EEG results and focused on connecting urban design and neuroscience to show the results. This new field of research can enhance the urban design to improve based on scientific knowledge and studies.

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